

## DESCRIPTION

PHASE MODULATING APPARATUS, COMMUNICATION DEVICE,  
MOBILE WIRELESS UNIT, AND PHASE MODULATING METHOD

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## Technical Field

[0001] The present invention relates to a phase modulation apparatus or the like that performs phase modulation using a PLL (Phase Locked Loop) circuit, and  
10 more particularly to a multimode capable phase modulation apparatus used as a communication device, such as a mobile phone or suchlike mobile communication device, or a base station that performs communication with a mobile communication device, a communication device and mobile  
15 radio device, and a phase modulation method.

## Background Art

[0002] Conventionally, a PLL circuit is generally utilized in a phase modulation apparatus used in a  
20 communication device. Requirements of a phase modulation method used by such a PLL circuit include low cost, low power consumption, good noise characteristics, and high modulation precision. In order to increase modulation precision, it is desirable for the PLL  
25 frequency bandwidth (hereinafter referred to as "PLL bandwidth") to be made wider than the frequency bandwidth of a modulation signal (hereinafter referred to as

"modulation bandwidth") in the phase modulation method of such a PLL circuit. However, since noise characteristics degrade when the PLL bandwidth is widened, the result is that it is difficult to widen the modulation  
5 bandwidth and perform wideband modulation.

[0003] Thus, a 2-point modulation method has been proposed whereby the PLL bandwidth is set narrower than the modulation bandwidth, and modulation within the PLL bandwidth and modulation outside the PLL bandwidth are  
10 performed at two different places (see, for example, Patent Document 1). FIG.1 is a block diagram showing the configuration of a phase modulation apparatus according to the prior art proposed in Patent Document 1. As shown in FIG.1, the configuration of a phase modulation  
15 apparatus using a 2-point modulation method such as proposed in Patent Document 1 comprises a PLL circuit 20 that includes a reference oscillator 21, a limiter 22, a reference frequency divider 23, a phase frequency detector 24, a charge pump 25, a loop filter 26, an adder  
20 27, a VCO (Voltage Controlled Oscillator) 28, and a frequency divider 29; as well as a modulator 30, an adder 31, a constant F 32, a delta sigma modulator 33, an adder 34, a constant P 35, a charge pump scaling section 36, and a modulation scaling section 37.

25 [0004] In FIG.1, VCO 28 of PLL circuit 20 outputs an RF phase modulation signal of a frequency in accordance with the voltage input to the control voltage terminal of VCO

28. Frequency divider 29 divides the frequency of the RF phase modulation signal output from VCO 28. Phase frequency detector 24 compares the phase of the signal output from frequency divider 29 with the phase of a reference signal output from reference frequency divider 23, and outputs a signal in accordance with the phase difference. Loop filter 26 averages the output signal from phase frequency detector 24.

[0005] Modulation amplitude scaling section 37 outputs a modulation signal from adder 27 to VCO 28 based on modulation data. Charge pump scaling section 36 controls residual modulation within the phase locked loop by controlling charge pump 25, and thereby enables modulation to be output more accurately. That is to say, the phase modulation apparatus in FIG.1 generates an RF phase modulation signal by supplying control signals from two points - charge pump scaling section 36 and modulation amplitude scaling section 37. In this way, a phase modulation apparatus using a 2-point modulation method makes it possible to implement multimode phase modulation covering the range from narrowband to broadband.

Patent Document 1: Unexamined Japanese Patent Publication No.2003-510899

## 25 Disclosure of Invention

### Problems to be Solved by the Invention

[0006] However, with the phase modulation apparatus

disclosed in Patent Document 1 above, when a narrow PLL bandwidth is set there is naturally a large modulation area outside the PLL band, and there is consequently a problem of stringent design specifications for VCO 28.

5 Also, when the modulation band differs according to the mode of the communication device, as with a multimode terminal that implements the gamut from narrowband modulation to wideband modulation, if the modulation bandwidth is sufficiently smaller than the PLL bandwidth, 10 for instance, (for example, if sufficiently smaller than the normal PLL bandwidth as in the case of the GSM mode modulation bandwidth), the influence of a signal outside the modulation band is felt when 2-point modulation is used, and therefore a characteristic such as modulation 15 precision (EVM: Error Vector Magnitude) may degrade, for example.

[0007] It is an object of the present invention to provide a multimode capable phase modulation apparatus that enables degradation of modulation precision to be reduced, 20 and also enables excessive power consumption to be suppressed, together with a communication device and mobile radio device incorporating that phase modulation apparatus, and a phase modulation method.

## 25 Means for Solving the Problems

[0008] A phase modulation apparatus of the present invention generates a phase modulation signal by

performing phase modulation on an input signal, and has a configuration that includes: a modulation signal generation section that generates a first baseband modulation signal and a second baseband modulation signal based on the input signal; a PLL circuit; and a switching section that switches between having the PLL circuit generate a phase modulation signal by performing 1-point modulation, or generate a phase modulation signal by performing 2-point modulation, by switching between inputting the first baseband modulation signal, or inputting the first baseband modulation signal and the second baseband modulation signal, to the PLL circuit, according to the communication mode.

[0009] Also, a phase modulation apparatus of the present invention has a configuration that further includes a determination section that performs a comparative determination of the size relationship of the modulation bandwidth corresponding to the communication mode and the bandwidth of the PLL circuit; wherein the switching section performs switching according to the control signal.

[0010] According to such a configuration, the PLL circuit is switched as appropriate between 1-point modulation and 2-point modulation by the switching section according to the communication mode, so that, for example, 1-point modulation is switched to in the case of a communication mode in which the modulation bandwidth is narrower than

the PLL bandwidth. As a result, a signal outside the modulation band is not output as a modulation signal, and therefore modulation precision is not degraded, and excess circuitry does not operate, enabling power consumption to be suppressed. On the other hand, in the case of a communication mode in which the modulation bandwidth is wider than the PLL bandwidth, 2-point modulation is switched to. By this means, it is possible to change the PLL bandwidth in the wider direction, reduce noise outside the PLL band, and improve noise characteristics.

#### Advantageous Effect of the Invention

[0011] According to a phase modulation apparatus of the present invention, according to differences of the communication mode of a communication device, switching is performed as appropriate between 1-point modulation and 2-point modulation, and also, the resonance frequency characteristics of a loop filter in the PLL are changed and/or the reference frequency of the PLL is changed, and the PLL bandwidth is optimized. By this means, noise characteristics in effect do not degrade even if the PLL bandwidth is widened (that is, even if wideband modulation is performed). Also, according to a phase modulation apparatus of the present invention, when the modulation bandwidth of a communication device is narrower than the PLL bandwidth, for example, switching to 1-point

modulation prevents a signal outside the modulation band from being output as a modulation signal, enabling degradation of modulation precision to be reduced, and also enabling excessive power consumption to be suppressed. As a result, it is possible to provide a multimode capable phase modulation apparatus that allows VCO design specifications to be relaxed, as well as a communication device and mobile radio device incorporating that phase modulation apparatus.

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#### Brief Description of Drawings

[0012]

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FIG.1 is a block diagram showing the configuration of a phase modulation apparatus according to the prior art;

FIG.2 is a block diagram showing the configuration of a phase modulation apparatus according to Embodiment 1 of the present invention;

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FIG.3 is a characteristic graph showing the relationship between the modulation bandwidth and PLL bandwidth applied to a phase modulation apparatus according to Embodiment 1 of the present invention;

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FIG.4 is a block diagram showing the configuration of a phase modulation apparatus according to Embodiment 2 of the present invention;

FIG.5 is a characteristic graph showing the relationship between the modulation bandwidth and PLL

bandwidth applied to a phase modulation apparatus according to Embodiment 2 of the present invention;

FIG.6 is an actual circuit diagram showing a sample configuration of a loop filter for implementing a change  
5 of PLL bandwidth in Embodiment 2 of the present invention;

FIG.7 is a block diagram showing the configuration of a phase modulation apparatus according to Embodiment 3 of the present invention;

FIG.8 is a characteristic graph showing the  
10 relationship between the modulation bandwidth and PLL bandwidth applied to a phase modulation apparatus according to Embodiment 4 of the present invention;

FIG.9 is an actual circuit diagram showing a sample configuration of a loop filter for implementing a change  
15 of PLL bandwidth in Embodiment 4 of the present invention;

FIG.10 is a block diagram showing a sample configuration of a transmitting apparatus incorporating a phase modulation apparatus of the present invention; and

20 FIG.11 is a block diagram showing a sample configuration of a communication device incorporating a phase modulation apparatus of the present invention.

Best Mode for Carrying Out the Invention

25 [0013]

Summary of the Invention

A phase modulation apparatus of the present



invention is provided in advance with a PLL that has a 2-point modulation method configuration, and has a switching section that is switched between 1-point modulation and 2-point modulation arbitrarily according to a difference of communication mode of a communication device. By this means, in the case of a communication device whose modulation bandwidth is narrowband, 1-point modulation is switched to by the switching section, the PLL bandwidth is made somewhat wider than the modulation bandwidth, and a signal outside the modulation bandwidth is not output as a modulation signal. By preventing a signal outside the modulation bandwidth from being output as a modulation signal in this way, degradation of modulation precision is eliminated and power consumption can be suppressed. On the other hand, in the case of a communication device whose modulation bandwidth is wideband, the PLL bandwidth is changed in the wideband direction by switchover to 2-point modulation by the switching section. Furthermore, by means of the switching section, the resonance frequency characteristics of a loop filter in the PLL are changed and/or the reference frequency of the PLL is increased, and the PLL bandwidth is changed in the wideband direction. By this means, noise outside the PLL band can be reduced and noise characteristics can be improved.

[0014]

(Embodiment 1)

Now, preferred embodiments of a phase modulation apparatus according to the present invention will be described in detail with reference to the accompanying drawings. In the drawings used in the embodiments  
5 described below, identical configuration elements are assigned the same codes, and duplicate descriptions are omitted wherever possible.

[0015]

FIG.2 is a block diagram showing the configuration  
10 of a phase modulation apparatus according to Embodiment 1 of the present invention. The phase modulation apparatus shown in FIG.2 has a configuration that includes a PLL circuit 15 that performs phase modulation of a transmit signal, a switching unit (switching section)  
15 9 that performs switching between 1-point modulation and 2-point modulation based on a mode setting signal determined for each mode of a communication device, a division ratio generation section 10 that sets a division ratio based on input of a first digital baseband signal  
20 S1 and a carrier signal, and outputs the set division ratio to a frequency divider 7, a filter 11 that removes a high-frequency component from a second digital baseband signal S2 output from a D/A converter 12, D/A converter 12 that converts second digital baseband signal S2 output  
25 from a modulation signal generation section 13 to an analog signal, and modulation signal generation section 13 that generates first digital baseband signal S1 and second

digital baseband signal S2 based on an input transmit signal.

[0016] PLL circuit 15 is composed of a crystal oscillator or suchlike reference oscillator 1 that generates a reference signal, a phase comparator 4 that compares the phase of a signal output from frequency divider 7 with the phase of the reference frequency divider, and outputs a signal in accordance with the phase difference, a loop filter 5 that averages the output signal from phase comparator 4, a VCO 6 that generates and outputs an RF phase modulation signal based on a transmit signal input from modulation signal generation section 13, frequency divider 7 that performs frequency division of an RF modulation signal output from VCO 6, and inputs the resulting signal to phase comparator 4, and an adder 8 that adds an output signal output from filter 11 to an output signal output from loop filter 5.

[0017] Next, the operation of the phase modulation apparatus shown in FIG.2 will be described. As the operations whereby a phase modulation apparatus performs phase modulation of a transmit signal, and generates and outputs an RF phase modulation signal, are well known, descriptions thereof will be omitted as far as possible, and the description will focus on operations whereby switching between 1-point modulation and 2-point modulation is performed according to a mode setting related to the present invention.

[0018] VCO 6 of PLL circuit 15 outputs an RF phase modulation signal based on the transmit signal input to modulation signal generation section 13, and the oscillation frequency of this RF phase modulation signal varies according to the voltage input to the control voltage terminal of VCO 6. This kind of control is implemented by having frequency divider 7 divide the frequency of the RF phase modulation signal output from VCO 6 and feed this back to phase comparator 4, having phase comparator 4 compare the phase of the signal input from frequency divider 7 with the phase of reference oscillator 1, and output a signal in accordance with the phase difference to loop filter 5, and having loop filter 5 average the output signal from phase comparator 4 and input the resulting signal to the control voltage terminal of VCO 6.

[0019] At this time, when modulation signal generation section 13 generates first digital baseband signal S1 and second digital baseband signal S2 based on the input transmit signal, division ratio generation section 10 sets a division ratio based on first digital baseband signal S1 and carrier signal input, and outputs the set division ratio to frequency divider 7. Frequency divider 7 then generates a modulation signal within the PLL circuit 15 based on the output signal from division ratio generation section 10. This is the modulation operation by means of the first modulation point.

[0020] The transmission route of second digital baseband signal S2 output from modulation signal generation section 13 comprises D/A converter 12 that converts second digital baseband signal S2 from a digital signal to an analog signal, filter 11 that removes a high-frequency component from the output signal output from D/A converter 12, and an adder 8 that adds an output signal output from filter 11 to an output signal output from loop filter 5. The output signal output from filter 11 (that is, second digital baseband signal S2) is then added by adder 8 in PLL circuit 15. By having adder 8 add together the output signal output from loop filter 5 and second digital baseband signal S2 output from filter 11 in this way, modulation outside the PLL circuit 15 band can be applied to the VCO 6 input signal. This is the modulation operation by means of the second modulation point.

[0021] Switching unit 9 is provided with a table in which the correspondence between the modulation bandwidth and the mode setting signal is set for each communication mode of the communication device. Therefore, switching unit 9 identifies the modulation bandwidth according to the mode setting signal set for each mode of the communication device, and if that modulation bandwidth is narrower than the PLL bandwidth, turns OFF the second digital baseband signal S2 route. By this means, PLL circuit 15 becomes a 1-point modulation circuit that performs modulation using only first digital baseband

signal S1 from division ratio generation section 10. On the other hand, if the modulation bandwidth set according to the communication device mode is wider than the PLL bandwidth, switching unit 9 turns ON the second digital  
5 baseband signal S2 route. By this means, PLL circuit 15 becomes a 2-point modulation circuit that performs modulation using first digital baseband signal S1 from division ratio generation section 10 and second digital baseband signal S2 from filter 11.

10 [0022] The nature of the frequency bands switched between for each communication device mode setting will now be explained using the accompanying drawings. FIG.3 is a characteristic graph showing the relationship between the modulation bandwidth and PLL bandwidth applied to  
15 a phase modulation apparatus according to Embodiment 1 of the present invention. In FIG.3, the horizontal axis indicates frequency, and the vertical axis indicates signal gain. For example, when a multimode phase modulation apparatus is implemented that combines GSM  
20 (Global System for Mobile) applied to a TDMA (Time Division Multiple Access) digital mobile phone system and UMTS (Universal Mobile Telecommunication System) applied to a third-generation (3G) mobile communication system, the modulation bandwidth is as shown in FIG.3, with narrowband  
25 modulation performed in GSM mode and wideband modulation performed in UMTS mode.

[0023] Since the GSM mode modulation bandwidth is

considerably narrower than bandwidth  $H(s)$  of PLL band (a), if 2-point modulation is performed PLL bandwidth  $H(s)$  becomes still wider and out-of-band modulation is also performed, with the result that characteristics  
5 degrade. Therefore, in the case of GSM mode, in which the modulation bandwidth is narrowband, switching unit 9 in FIG. 2 is turned OFF and 1-point modulation is performed using only first digital baseband signal  $S_1$ , and control is performed so that modulation outside the PLL band is  
10 stopped. On the other hand, in UMTS mode, in which the modulation bandwidth is wideband, 2-point modulation comprising PLL circuit 15 in-band modulation and out-of-band modulation is performed using first digital baseband signal  $S_1$  and second digital baseband signal  
15  $S_2$  by turning switching unit 9 ON, and wideband modulation is implemented.

[0024] By switching switching unit 9 so that switching unit 9 is turned OFF and 1-point modulation is performed in the case of narrowband modulation (that is, in GSM  
20 mode), and switching unit 9 is turned ON and 2-point modulation is performed in the case of wideband modulation (that is, in UMTS mode), as described above, modulation ranging from narrowband to wideband can be implemented with one circuit. By this means, in 1-point modulation  
25 corresponding to narrowband GSM mode, modulation precision can be improved since modulation outside the PLL band is not performed. Furthermore, since 1-point

modulation is used, the number of elements operating in the phase modulation apparatus can be reduced, enabling current dissipation to be decreased. Also, in 2-point modulation corresponding to wideband UMTS mode, wideband modulation can be implemented by performing 2-point modulation comprising PLL in-band modulation and out-of-band modulation.

[0025] Switching unit 9 that performs switching between 1-point modulation and 2-point modulation need not be a switch. Since adder 8 is used in PLL circuit 15, as shown in FIG.2, this adder 8 can be employed to switch between 1-point modulation and 2-point modulation. That is to say, if the output of D/A converter 12 is controlled at zero, second digital baseband signal S2 is not added by adder 8, effectively resulting in 1-point modulation, and if the output of D/A converter 12 is controlled normally, second digital baseband signal S2 is added, resulting in 2-point modulation. Thus switching between 1-point modulation and 2-point modulation can also be achieved easily by using this kind of control method.

[0026]

(Embodiment 2)

FIG.4 is a block diagram showing the configuration of a phase modulation apparatus according to Embodiment 2 of the present invention. As compared with the phase modulation apparatus of Embodiment 1 shown in FIG.2, the configuration of a phase modulation apparatus according



to Embodiment 2 of the present invention shown in FIG.4 additionally includes a determination section 14 that identifies a modulation bandwidth corresponding to the mode setting of each communication device and performs  
5 ON/OFF switching of switching unit 9, and also sends out a control signal for changing the PLL bandwidth (that is, the loop filter bandwidth). Determination section 14 is provided with a table in which a modulation bandwidth is set for each communication device mode.

10 [0027] Determination section 14 references the table in which a modulation bandwidth is set for each communication device mode, identifies the modulation bandwidth by means of a mode setting signal, and sends control signals to switching unit 9 and loop filter 5. By this means,  
15 switching between 1-point modulation and 2-point modulation is performed by turning switching unit 9 ON/OFF according to the communication mode of a communication device, and also, the resonance frequency of loop filter 5 is changed and the bandwidth of PLL circuit 15 is  
20 switched.

[0028] The operations whereby determination section 14 performs switching control of the bandwidth of PLL circuit 15 according to the communication mode of a communication device are described below. FIG.5 is a characteristic  
25 graph showing the relationship between the modulation bandwidth and PLL bandwidth applied to a phase modulation apparatus according to Embodiment 2 of the present

invention, and FIG.6 is an example of an actual circuit diagram of loop filter 5 for implementing a change of PLL bandwidth in the phase modulation apparatus shown in FIG.4.

5 [0029] As shown in FIG.5, when there are two modulation modes, narrowband modulation GSM mode and wideband modulation UMTS mode, the GSM mode narrowband modulation width is considerably narrower than bandwidth  $H(s)$  of the PLL band, and therefore if 2-point modulation is performed, out-of-band modulation is also performed, with  
10 the result that characteristics degrade. Thus, determination section 14 references the table in which a modulation bandwidth is set for each communication device mode, determines that GSM mode is a mode in which  
15 the modulation bandwidth is narrowband, and sends a control signal to switching unit 9 to turn switching unit 9 OFF and perform 1-point modulation so that modulation outside the PLL band is not performed. As a result, narrowband mode 1-point modulation is performed using  
20 only first digital baseband signal S1.

[0030] At this time, determination section 14 does not send a control signal to loop filter 5, and therefore switch SW1 of the loop filter comprising a series-parallel circuit of capacitors and resistances in FIG.6 is in the  
25 OFF state. Consequently, loop filter 5 has a circuit configuration in which resistance  $R_x$  is inserted in series with resistance  $R$ , and thus the frequency is lowered,

the resonance point is lowered, and the bandwidth is narrowed. Therefore, as regards the bandwidth of PLL circuit 15, bandwidth  $H(s)$  becomes narrow as indicated by the PLL band (a) solid line in FIG.5. However, the bandwidth of PLL band (a) is wider than the GSM mode bandwidth. By thus preventing a signal outside the modulation band from being output as a modulation signal, degradation of modulation precision is eliminated and power consumption can be suppressed.

10 [0031] Also, in wideband modulation UMTS mode, determination section 14 references the table in which a modulation bandwidth is set for each communication device mode, determines that UMTS mode is a mode in which the modulation bandwidth is wideband, and sends a control  
15 signal to switching unit 9 to turn switching unit 9 ON and perform 2-point modulation so that modulation outside the PLL band is performed. As a result, wideband mode 2-point modulation is performed using first digital baseband signal S1 and second digital baseband signal  
20 S2.

[0032] At this time, determination section 14 sends a control signal to loop filter 5, and therefore switch SW1 of the loop filter comprising a series-parallel circuit of capacitors and resistances in FIG.6 is turned  
25 ON. Consequently, loop filter 5 has a circuit configuration in which resistance Rx is shorted, and thus the frequency rises, the resonance point rises, and the

bandwidth is widened. Therefore, as regards the bandwidth of PLL circuit 15 shown in FIG.5, the bandwidth widens in the direction indicated by the arrow from the PLL band (a) solid line to the PLL band (b) indicated by a dotted line. By thus performing control so that switching unit 9 is turned ON in wideband modulation UMTS mode, control is implemented so that 2-point modulation is switched to and the resonance point of loop filter 5 is changed, and PLL bandwidth  $H(s)$  is made wider than in GSM mode.

[0033] By turning ON switch SW1 in FIG.6 and changing the resistance value in wideband modulation UMTS mode as described above, thereby making the modulation area outside the PLL band (that is, the area of the hatched part in FIG.5) smaller, the effects of characteristic degradation due to VCO 6 sensitivity and linearity are reduced, enabling VCO 6 to be given a noise margin, and as a result, making it possible to relax the VCO design specifications.

[0034]

(Embodiment 3)

FIG.7 is a block diagram showing the configuration of a phase modulation apparatus according to Embodiment 3 of the present invention. As compared with the phase modulation apparatus of Embodiment 2 shown in FIG.4, the configuration of a phase modulation apparatus according to Embodiment 3 of the present invention shown in FIG.7

additionally includes a limiter 2 that sends a reference signal of reference oscillator 1 to a reference frequency divider 3, and reference frequency divider 3 that performs frequency division and frequency multiplication of the reference signal and outputs the resulting signal to phase comparator 4 as a reference signal. Therefore, in FIG.7, limiter 2 and reference frequency divider 3 have been added to the configuration of PLL circuit 15 in FIG.2 and FIG.4, and the PLL circuit reference code has been changed to 15a.

[0035] In FIG.7, determination section 14 is provided with a table in which a modulation bandwidth is set for each communication device mode, references this table and identifies the modulation bandwidth by means of a mode setting signal, and sends control signals to switching unit 9, division ratio generation section 10, and reference frequency divider 3. By this means, switching between 1-point modulation and 2-point modulation is performed by turning switching unit 9 ON/OFF according to the communication device mode, and also, the division ratio of division ratio generation section 10 and the frequency of the reference frequency division signal of reference frequency divider 3 are changed, and the bandwidth of PLL circuit 15a is altered.

[0036] The operations whereby determination section 14 performs switching between 1-point modulation and 2-point modulation by turning switching unit 9 ON/OFF according

to the communication device mode are the same as in above-described Embodiment 1 and Embodiment 2, and therefore a description thereof is omitted here. In Embodiment 3, determination section 14 further references  
5 the table in which a modulation bandwidth is set for each communication mode, identifies the modulation bandwidth by means of a mode setting signal, and changes the reference oscillation frequency of reference frequency divider 3 output and the division ratio of division ratio generation  
10 section 10, and alters the PLL bandwidth, in performing modulation.

[0037] For example, when there are two modulation modes, narrowband modulation GSM mode and wideband modulation UMTS mode, as shown in FIG.5, the GSM mode bandwidth is  
15 considerably narrower than PLL bandwidth  $H(s)$ , and therefore if 2-point modulation is performed, out-of-band modulation is also performed, with the result that characteristics degrade. Therefore, switching unit 9 is turned OFF and 1-point modulation is performed so that  
20 modulation outside the PLL band is not performed.

[0038] At this time, determination section 14 does not send a control signal to reference frequency divider 3 or division ratio generation section 10, and therefore the operating frequency of PLL circuit 15a does not change,  
25 and as regards the bandwidth of PLL 15a, bandwidth  $H(s)$  becomes narrow as indicated by the PLL band (a) solid line in FIG.5. However, the bandwidth of PLL band (a)

is wider than the GSM mode modulation bandwidth. By thus preventing a signal outside the modulation band from being output as a modulation signal, degradation of modulation precision is eliminated and power consumption can be suppressed.

[0039] Also, in wideband modulation UMTS mode, determination section 14 sends a control signal to turn switching unit 9 ON, and switches to 2-point modulation. Furthermore, determination section 14 sends control signals to reference frequency divider 3 and division ratio generation section 10, increases the frequency of the reference oscillation output from reference frequency divider 3 and also increases the division ratio of division ratio generation section 10, thereby increasing the operating frequency of PLL circuit 15a and widening bandwidth  $H(s)$  of PLL circuit 15a as indicated by the dotted line marked PLL band (b). By increasing the reference oscillation frequency of PLL circuit 15a in wideband modulation UMTS mode as described above, the bandwidth of PLL circuit 15a can be made wider than when switching unit 9 is OFF, therefore modulating outside the PLL band can be reduced, and the effects of characteristic degradation due to VCO 6 sensitivity and linearity are reduced, enabling VCO 6 design specifications to be relaxed.

[0040]

(Embodiment 4)

In Embodiment 4, a case is described in which three PLL bandwidths are set, switching among three communication modes. Here, the three communication modes for which setting switching is described are the  
5 above-described GSM mode, Bluetooth mode used in systems for radio data transfer between mobile devices, and the above-described UMTS mode.

[0041] FIG.8 is a characteristic graph showing the relationship between the modulation bandwidth and PLL  
10 bandwidth applied to a phase modulation apparatus according to Embodiment 4 of the present invention, and FIG.9 is an example of a circuit diagram that implements a change of PLL bandwidth in Embodiment 4 of the present invention. Operations whereby the PLL bandwidth is  
15 switched optimally for each communication mode are described below using FIG.8 and FIG.9.

[0042] In GSM mode, which has the narrowest band, the modulation bandwidth is considerably narrower than the PLL bandwidth, and therefore if 2-point modulation is  
20 performed, out-of-band modulation is also performed, with the result that characteristics degrade. Therefore, 1-point modulation is selected by turning switching unit 9 in FIG.4 OFF so that modulation outside the PLL band is not performed. As a result, the bandwidth of PLL  
25 becomes PLL band (a) indicated by a solid line in FIG.8, and the PLL bandwidth is somewhat wider than the GSM mode modulation bandwidth. At this time, GSM modulation



precision improves since modulation outside the PLL band is not performed, and few elements operate since 1-point modulation is used, reducing power consumption.

[0043] In Bluetooth mode, which covers a somewhat wider  
5 band than GSM mode, 2-point modulation is switched to  
by performing control so that switching unit 9 in FIG.4  
is turned ON, control is performed so that the PLL bandwidth  
is made wider than in GSM mode, and the PLL bandwidth  
is as indicated by the PLL band (b) dotted line in FIG.8.  
10 However, since PLL band (b) is narrower than the Bluetooth  
mode modulation bandwidth, switch SW1 of the loop filter  
in FIG.9 is turned OFF, and a switch SW2 is turned ON.  
As a result, series resistance  $R_y$  is shorted, the resonance  
frequency increases, and the PLL bandwidth widens and  
15 becomes the PLL band (c) PLL bandwidth as indicated by  
a dotted line in FIG.8. That is to say, with the change  
to PLL band (c), the PLL bandwidth becomes wider than  
the Bluetooth mode modulation bandwidth, and decreasing  
the area of modulation outside the PLL band reduces the  
20 effects of characteristic degradation due to VCO 6  
sensitivity and linearity, enabling the VCO 6 design  
specifications to be relaxed.

[0044] In UMTS mode, which has the widest band, 2-point  
modulation is left set by leaving switching unit 9 in  
25 FIG.4 turned ON, and switch SW1 of the loop filter in  
FIG.9 is turned ON. At this time, it does not matter  
whether switch SW2 is ON or OFF. As a result, series

resistances  $R_y$  and  $R_x$  are shorted and the resonance frequency further increases, and the PLL bandwidth widens further to cover PLL band (d) as indicated by a dotted line in FIG.8. By performing control so that the PLL bandwidth is made wider in UMTS mode than in Bluetooth mode as described above, thereby decreasing the area of modulation outside the PLL band (that is, making the area of the hatched part in FIG.8 smaller), the effects of characteristic degradation due to VCO 6 sensitivity and linearity can be reduced, and as a result, the VCO 6 design specifications can be relaxed.

[0045] In Bluetooth mode, even if switching unit 9 in FIG.4 is turned OFF and 1-point modulation is switched to, the PLL bandwidth can be widened as indicated by PLL band (c) by turning ON switch SW1 of the loop filter in FIG.9. As a result, the PLL bandwidth becomes wider than the Bluetooth mode modulation bandwidth, and decreasing the area of modulation outside the PLL band reduces the effects of characteristic degradation due to VCO 6 sensitivity and linearity, enabling the VCO 6 design specifications to be relaxed. The relationship between the modulation bandwidth and PLL bandwidth is determined as appropriate according to the relationship between the VCO characteristics and noise outside the PLL band.

[0046]

(Embodiment 5)

In Embodiment 5, a phase modulation apparatus as

described in the above embodiments can also be applied to a configuration incorporated in a communication device or mobile radio device (such as a mobile phone or the like), a portable communication terminal such as a notebook-type personal computer, or a communication apparatus such as a radio base station. FIG.10 is a block diagram showing a sample configuration of a transmitting apparatus incorporating a phase modulation apparatus of the present invention. Transmitting apparatus 900 has a configuration that includes a transmit data signal input terminal 901, an amplitude/phase component extraction section 902, an amplitude signal processing section 903, a phase modulation section 904, a nonlinear amplification section 905, and a transmission output terminal 906. In this case, a phase modulation apparatus according to any of the above-described embodiments can be installed in phase modulation section 904.

[0047] When a transmit data signal is input from transmit data signal input terminal 901, an amplitude component modulation signal and a phase component modulation signal are extracted from the transmit data signal by amplitude/phase component extraction section 902. Then the power supply voltage value of nonlinear amplification section 905 is set via amplitude signal processing section 903 according to the amplitude component modulation signal. Also, a phase modulated wave in which a carrier having an angular frequency is phase modulated by the

phase component modulation signal is generated by phase modulation section 904, and input to nonlinear amplification section 905.

[0048] Then a signal obtained by multiplying together  
5 the nonlinear amplification section 905 power supply voltage value, and the phase modulated wave that is the output signal from phase modulation section 904, is amplified by gain  $G$  of nonlinear amplification section 905, and output in the nonlinear amplification section  
10 905 output as an RF vector modulated wave (RF modulation signal). Since the modulated wave input to nonlinear amplification section 905 is a phase modulated wave that is a modulated wave of a fixed envelope level, a highly efficient nonlinear amplifier can be used as a  
15 high-frequency amplifier. Such a configuration enables a small, low-cost transmitting apparatus 900 to be implemented.

[0049] FIG.11 shows the general configuration of a communication device incorporating a phase modulation  
20 apparatus of the present invention. Communication device 1000 is equipped with a transmitting apparatus 900 incorporating a phase modulation apparatus of the present invention, a receiving apparatus 910 that obtains a receive data signal by executing predetermined  
25 reception processing including demodulation processing on a received signal, a duplexer 920 that performs switching between a transmit signal and received signal,

and an antenna 930.

[0050] A phase modulation apparatus of the present invention is provided in communication device 1000 of this embodiment as described above. As described in the  
5 above embodiments, a phase modulation apparatus of the present invention can achieve an improvement in noise characteristics and also suppress power consumption, and therefore using a communication device that employs this phase modulation apparatus has an effect of enabling a  
10 high-quality signal to be transmitted while keeping power consumption low when performing multimode compatible transmission.

[0051] As described above, according to one aspect of a phase modulation apparatus of the present invention,  
15 the phase modulation apparatus generates a phase modulation signal by performing phase modulation on an input signal, and has a configuration that includes: a modulation signal generation section that generates a first baseband modulation signal and a second baseband  
20 modulation signal based on the input signal; a PLL circuit; and a switching section that switches between having the PLL circuit generate a phase modulation signal by performing 1-point modulation, or generate a phase modulation signal by performing 2-point modulation, by  
25 switching between inputting the first baseband modulation signal, or inputting the first baseband modulation signal and the second baseband modulation signal, to the PLL

circuit, according to the communication mode.

[0052] Also, according to one aspect of a phase modulation apparatus of the present invention, the phase modulation apparatus has a configuration that further  
5 includes a determination section that performs a comparative determination of the size relationship of modulation bandwidth according to the communication mode and the bandwidth of the PLL circuit; wherein the switching section performs switching according to the control  
10 signal.

[0053] According to such a configuration, the PLL circuit is switched as appropriate between 1-point modulation and 2-point modulation by the switching section according to the communication mode, so that, for example, 1-point  
15 modulation is switched to in the case of a communication mode in which the modulation bandwidth is narrower than the PLL bandwidth. As a result, a signal outside the modulation band is not output as a modulation signal, and therefore modulation precision is not degraded, and  
20 excess circuitry does not operate, enabling power consumption to be suppressed. On the other hand, in the case of a communication mode in which the modulation bandwidth is wider than the PLL bandwidth, 2-point modulation is switched to. By this means, it is possible  
25 to change the PLL bandwidth in the wider direction, reduce noise outside the PLL band, and improve noise characteristics.

[0054] Also, according to one aspect of a phase modulation apparatus of the present invention, the phase modulation apparatus has a configuration wherein the determination section sends a control signal to a loop  
5 filter that is a component of the PLL circuit; and the loop filter changes its own resonance frequency based on the control signal sent from the determination section, and changes the bandwidth of the PLL circuit.

[0055] According to this configuration, the resonance  
10 frequency of the loop filter can be varied, and the bandwidth of the PLL circuit changed, according to a control signal corresponding to the communication mode. For example, when the modulation bandwidth of the communication mode is wider than the PLL bandwidth, the  
15 resonance frequency of the loop filter is increased by a control signal, and the PLL circuit bandwidth is changed in the wideband direction. By this means, degradation of noise characteristics in a wideband communication mode can be prevented. Therefore, the design specifications  
20 of a voltage controlled oscillator that is a component of the PLL circuit can be relaxed.

[0056] Also, according to one aspect of a phase modulation apparatus of the present invention, the phase modulation apparatus has a configuration wherein the  
25 determination section sends the control signal to a reference frequency divider that provides a reference signal to a phase comparator of the PLL circuit and a

division ratio generation section that generates the division ratio of the PLL circuit, changes the oscillation frequency of the reference frequency divider and the division ratio of the division ratio generation section, and changes the bandwidth of the PLL circuit.

[0057] According to this configuration, it is possible to vary the oscillation frequency of the reference frequency divider that is a component of the PLL circuit, and the division ratio of the division ratio generation section, and change the bandwidth of the PLL circuit. For example, when the modulation bandwidth of the communication mode is wider than the PLL bandwidth, the oscillation frequency of the reference frequency divider is increased by a control signal, and the PLL circuit bandwidth is changed in the wideband direction. By this means, degradation of noise characteristics in a wideband communication mode can be prevented. Therefore, the design specifications of a voltage controlled oscillator that is a component of the PLL circuit can be relaxed.

[0058] Also, according to one aspect of a phase modulation apparatus of the present invention, the phase modulation apparatus has a configuration wherein the communication modes are of two kinds, GSM mode and UMTS mode; and the determination section sends a control signal to the switching section so that 1-point modulation is performed in the GSM mode, and sends a control signal to the switching section so that 2-point modulation is



performed in the UMTS mode.

[0059] According to this configuration, in narrowband GSM mode, 1-point modulation is performed, and therefore modulation precision can be improved since modulation  
5 outside the PLL band is not performed. Also, since 1-point modulation is performed, few elements operate, and current dissipation can be reduced. Furthermore, in wideband UMTS mode, 2-point modulation is performed, and therefore wideband modulation can be implemented by  
10 performing 2-point modulation comprising PLL in-band modulation and out-of-band modulation.

[0060] Also, according to one aspect of a phase modulation apparatus of the present invention, the phase modulation apparatus has a configuration wherein the  
15 communication modes are of two kinds, GSM mode and UMTS mode; and the determination section sends a control signal to the switching section so that 1-point modulation is performed in the GSM mode; and in the UMTS mode, sends a control signal to the switching section so that 2-point  
20 modulation is performed, and also sends a control signal to the loop filter and changes the bandwidth of the PLL circuit in the wideband direction.

[0061] According to this configuration, in wideband UMTS mode, 2-point modulation is performed, the resonance  
25 frequency of the loop filter is increased, and the bandwidth of the PLL circuit is changed in the wideband direction. By this means, degradation of noise

characteristics in a wideband communication mode can be prevented.

[0062] Also, according to one aspect of a phase modulation apparatus of the present invention, the phase modulation apparatus has a configuration wherein the communication modes are of three kinds, GSM mode, Bluetooth mode, and UMTS mode; and the determination section sends a control signal to the switching section so that 1-point modulation is performed in the GSM mode; and in the Bluetooth mode, sends a control signal to the switching section so that 2-point modulation is performed, and also sends a control signal to the loop filter and changes the bandwidth of the PLL circuit in the wideband direction; and in the UMTS mode, sends a control signal to the switching section so that 2-point modulation is performed, and also sends a control signal to the loop filter and changes the bandwidth of the PLL circuit further in the wideband direction than in the case of the Bluetooth mode.

[0063] According to this configuration, in GSM mode, which has the narrowest band, 1-point modulation is performed and the PLL bandwidth is made somewhat wider than the GSM mode modulation bandwidth. In Bluetooth mode, in which the bandwidth is somewhat wider than in GSM mode, 2-point modulation is performed, and also the resonance frequency of the loop filter is increased and the PLL bandwidth is made somewhat wider than the Bluetooth mode

modulation bandwidth. Furthermore, in UMTS mode, which has the widest band, 2-point modulation is performed, and also the resonance frequency of the loop filter is further increased and the PLL bandwidth is widened further than in Bluetooth mode. By this means, wideband modes can be catered for simply by performing switching according to the communication mode using a single phase modulation apparatus.

[0064] According to the present invention, it is also possible to implement a communication device or mobile radio device incorporating a phase modulation apparatus of any of the above-described embodiments.

[0065] According to this configuration, it is possible to provide a communication device or mobile radio device incorporating a multimode capable phase modulation apparatus that enables VCO design specifications to be relaxed.

[0066] Also, according to one aspect of a phase modulation method of the present invention, the phase modulation method generates a phase modulation signal by performing phase modulation on a transmit signal, and includes: a step of performing a comparative determination of the size relationship of the modulation bandwidth of the communication mode and the bandwidth of the PLL circuit; a step of switching the PLL circuit to 1-point modulation when the modulation bandwidth of the communication mode is narrowband compared with the

bandwidth of the PLL circuit, and switching the PLL circuit to 2-point modulation when the modulation bandwidth of the communication mode is wideband compared with the bandwidth of the PLL circuit; and a step of, when the  
5 PLL circuit is switched to 2-point modulation, changing the resonance frequency of the loop filter of that PLL circuit and changing the bandwidth of the PLL circuit in the wideband direction.

[0067] Furthermore, according to one aspect of a phase  
10 modulation method of the present invention, the phase modulation method generates a phase modulation signal by performing phase modulation on a transmit signal, and includes: a step of performing a comparative determination of the size relationship of the modulation  
15 bandwidth of the communication mode and the bandwidth of the PLL circuit; a step of switching the PLL circuit to 1-point modulation when the modulation bandwidth of the communication mode is narrowband compared with the bandwidth of the PLL circuit, and switching the PLL circuit  
20 to 2-point modulation when the modulation bandwidth of the communication mode is wideband compared with the bandwidth of the PLL circuit; and a step of, when the PLL circuit is switched to 2-point modulation, changing the reference frequency of that PLL circuit and changing  
25 the bandwidth of the PLL circuit in the wideband direction.

[0068] The present application is based on Japanese Patent Application No.2004-373801 filed on December 24,

2004, entire content of which is expressly incorporated herein by reference.

#### Industrial Applicability

- 5 [0069] A phase modulation apparatus according to the present invention can improve modulation precision, and also achieve low power consumption and multimode operation, by performing a change of bandwidth of a loop filter in a PLL circuit, a change of reference oscillation
- 10 frequency in the PLL circuit, and switching between 1-point modulation and 2-point modulation, as a result of which VCO design specifications can be relaxed, and is therefore suitable for use as a phase modulation apparatus incorporated in a portable communication
- 15 terminal such as a mobile phone, radio communication device, notebook-type personal computer, or the like, or a communication apparatus such as a mobile communication device or radio base station.